INTRODUCTION

FOREWORD

The *Sight Reduction Tables for Air Navigation* consist of three volumes of comprehensive tables of altitude and azimuth designed for the rapid reduction of astronomical sights in the air. This volume (Volume **2**), for latitudes 0°–40°, and Volume **3** for latitudes 39°–89°, provide for sights of the Sun, Moon, and planets; these tables are permanent. Volume **1** contains tables for selected stars for all latitudes, calculated for a specific epoch; it is intended for use for about 5 years, when it will be replaced by a new edition based on a later epoch.

The National Imagery and Mapping Agency is responsible for the compilation of these tables. The Nautical Almanac Office of the U.S. Naval Observatory and H. M. Nautical Almanac Office have cooperated in their design and preparation.

The tables are published in the United Kingdom as A.P. 3270, *Sight Reduction Tables for Air Navigation*.

The content and format of these three volumes may not be changed without the approval of Working Party 70 of the Air Standardization Coordinating Committee.

In this 1992 reprint, the basic information and tabular data remain unchanged. Previous printings of this volume need not be replaced by this reprint.

Users should refer corrections, additions, and comments for improving this product to:

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INTRODUCTION

DESCRIPTION OF THE TABLES

These tables, designated as Volume **2** of the three-volume series of **Pub. No. 249**, *Sight Reduction Tables for Air Navigation*, together with the similar Volume **3**, supplement Volume **1** containing tabulations for selected stars. They together contain values of the altitude (to the nearest minute) and the azimuth angle (to the nearest degree) for integral degrees of declination from 29° north to 29° south, for the complete range of latitude and for all hour angles at which the zenith distance is less than 95° (97° between latitudes 70° and the poles); provision is made for interpolation for declination. As in Volume **1**, no correction for refraction has been included in the tabulated altitudes; azimuth angle is given in contrast to the azimuth for the selected stars. Volume **2** caters for latitudes 0°–40° and Volume **3** for latitudes 39°–89°; they are divided purely for convenience in handling, and are otherwise similar in all respects.

The tables have been designed for use with the *Air Almanac* in the reduction of sights of the Sun, Moon and planets; they may also be used for stars with declinations less than 30° north or south. A list of the 57 navigational stars, with their positions, is given on page (iii), as well as in the *Air Almanac*.

Their compact arrangement reflects the desire to include the maximum amount of data in the smallest practicable space. The range of declination, and the extension to negative altitudes, explains the necessity for arranging the tables across the length of the page.

ENTERING ARGUMENTS AND ARRANGEMENT

Latitude. Tabulations are given, in the two Volumes **2** and **3**, for every whole degree of latitude from 0° to 89°; there are four pages for latitude 0°, six pages for latitudes 1° to 47°, eight pages for latitudes 48° to 69°, four pages for latitudes 70° to 74° and six pages for latitudes 75° to 89°. Volume **2** covers latitudes 0° to 40° and Volume **3** latitudes 39° to 89°.

Declination. The full range of declination is divided into two groups of 15 values: 0° to 14° and 15° to 29°. One or other of these groups is the horizontal argument on every page. Within the section (of 4, 6 or 8 pages) corresponding to each degree of latitude, tabulations (of 2, 3 or 4 pages) for the first group of declinations, 0° to 14°, are given first; when completed they are followed by precisely similar tabulations for the second group of declinations, 15° to 29°.

Local hour angle. The vertical argument on each page is the local hour angle of the body observed; it must be formed in the usual way from the *Air Almanac*. The interval is 1° for latitudes 0° to 69°, but is increased to 2° for latitudes 70° to 89°. Within each sub-section of latitude and declination group, tabulations are first given for declination of the *same* name as the latitude with LHA *increasing* on the left-hand side from 0° to 180°, or to some smaller limit depending on the altitude; on the right-hand side the argument decreases from 360° to 180° (or some larger limit). Tabulations for declination of the *contrary* name to the latitude follow after a break, and the order of LHA is reversed; the left-hand argument *decreases* from 180°, or generally from some smaller limit, to 0°, while the right-hand argument increases from 180° (or some larger limit) to 360°.

The tabulations for contrary name are seen to be arranged in the reverse way from those for same name; working backwards (upwards instead of downwards) from the end of the sub-section, they appear precisely as those for the same name when working forwards in the normal way.

Values of LHA between 0° and 180° are always found on the left; values between 180° and 360° are always found on the right.

For each combination of arguments are given the tabulated (or computed) altitude (Hc), the difference, *d*, between Hc and that for the next higher declination, and the azimuth angle, Z. Rules are given on each page for converting azimuth angle, Z, into azimuth, Zn.

INTRODUCTION

USE OF THE TABLES

The GHA and declination of the observed body are taken in the usual way from the *Air Almanac* for the actual time (GMT) of observation. The GHA is combined with an assumed longitude, close to the DR longitude, to make the LHA a whole degree, or an even degree for latitudes above 69°. The tables are first entered with the whole degree of latitude, nearest to the DR latitude, and the appropriate declination group; in this sub-section, they are then entered with the degree of declination numerically less than that of the body observed, and with the value of LHA found above, taking particular care to choose the portion of the table corresponding to the same or contrary name, as appropriate.

The tables give directly the tabulated altitude, Hc, the difference, *d*, and the azimuth angle, Z, for the whole degree of declination chosen. The altitude must be interpolated to the true declination by means of Table **5**, on page 248 or the bookmark, applying to it the correct proportion of *d*, with the sign given (added if +, subtracted if –); the azimuth angle, Z, must be converted to azimuth, Zn, by the rules given on each page, but, in general, need not be interpolated for declination. For zenith distances greater than 90°, negative altitudes are tabulated; the correction from Table **5** must thus be applied algebraically. In all cases it is recommended that values in neighboring columns be inspected to see whether the altitude increases or decreases with declination.

The intercept is found in the usual way by comparing the corrected sextant altitude (Ho) with the tabulated altitude, interpolated to the actual declination as above:

towards the body if the observed altitude is *greater* than the tabulated altitude;
away from the body if the observed altitude is *less* than the tabulated altitude.

The sextant reading must be corrected for instrument error, dome refraction (if applicable), refraction (from Table **6**) and parallax (for the Moon), before being compared with the tabulated altitude. The sight is plotted from the assumed position, defined by the whole degree of latitude and the assumed longitude. This assumed position may previously be adjusted for the effect of Coriolis acceleration (see Table **7**) and advanced or retarded to another time; alternatively these corrections may be made to the position line or, in the case of the corrections from Table **7**, to the fix. The application of these corrections is considered separately below.

Example. On 1978 January 1, in DR position S 23° 42′, E 113° 25′, at height 37,000 ft., an observation of the Moon is obtained with a bubble sextant at GMT $00^h\ 53^m\ 45^s$; the sextant reading is 31° 29′ and the correction for instrument error and dome refraction is –5′.

From the *Air Almanac*,	GMT	GHA	Dec.
	h m s	° ′	° ′
AM page for Jan. 1, Moon at	00 50 00	300 08	N 1 29
flap, Moon, increment for	3 45	0 54	
Sum = GHA Moon at	00 53 45	301 02	
Assumed longitude, added because east		+ 112 58	
Sum = LHA Moon (less 360° if necessary)		54	

	° ′
Sextant altitude	31 29
Instrument error, etc.	–5
Parallax in altitude (P. in A.)	+48
Refraction (Table **6**)	0
Corrected sextant altitude (Ho)	32 12

From these tables (pages 146), for Lat. 24°, Dec. 1° (Contrary), LHA 54°

		° ′	′	°		° ′	
Tabulated Hc, *d*, and Z,	Hc	32 00	*d* –30	Z 108	Corrected sextant altitude (Ho)	32 12	
d-correction (Table **5**) for 29′		–14			Corrected tabulated altitude (Hc)	31 46	
Corrected tabulated altitude (Hc)		31 46		Zn 288	Intercept	26	*towards*

The sign of the *d*-correction is the same as that of *d*, and a glance at the entries for the neighboring declination column (2°) verifies that the altitude decreases with increasing declination.

The assumed latitude is S 24°, the assumed longitude is E 112° 58′, and the intercept of 26′ is plotted from this position in the true bearing of 288°. The position line is drawn perpendicular to this direction.

A useful feature of these tables is the provision for low and even negative altitudes; this enables sights of the Sun, or other bodies, to be reduced when actually below the horizon as seen from sea level. Refraction at such low altitudes is large and variations from the standard values are too great to be ignored; provision is thus made in Table **6** for the application of a temperature correction in such cases.

Example. On 1978 January 1, in DR position S 16° 47′, W 32° 19′, at height 32,000 ft., an observation of the Sun is obtained at GMT $20^h\ 57^m\ 43^s$, the Sun being just above the visible horizon; the sextant reading is –2° 15′, the correction for instrument error and dome refraction is –8′, and the external temperature is –70°C.

From the *Air Almanac*,	GMT	GHA	Dec.		
	h m s	° ′	° ′		° ′
PM page for Jan. 1, Sun at	20 50 00	131 35	S 22 59	Sextant altitude	–2 15
flap, Sun, increment for	7 43	1 56		Instrument error, etc.	–8
Sum = GHA Sun at	20 57 43	133 31		Refraction (Table **6**)	–50
Assumed longitude, subtracted because west		–32 31		Corrected sextant altitude (Ho)	–3 13
Sum = LHA Sun (less 360° if necessary)		101			

From these tables (pages 106), for Lat. 17°, Dec. 22° (Same), LHA 101°

		° ′	′	°		° ′	
Tabulated Hc, *d*, and Z,	Hc	–3 25	*d* +20	Z 66	Corrected tabulated altitude (Ho)	–3 05	
d-correction (Table **5**) for 59′		+20			Intercept	8	*away*
Corrected tabulated altitude (Hc)		–3 05		Zn 246	plotted from assumed position: latitude S 17°, longitude W 32° 31′		

Refraction is obtained from Table **6**. The column headed 30,000 ft. (nearest to 32,000 ft.) is first chosen; in that column the sextant altitude corrected for instrument error, etc., (–2° 23′) is seen to lie in the interval corresponding to R_0 = 45′. However, the temperature is here lower than normal for the height and the lower portion of the table indicates that the correcting factor *f*, corresponding to a temperature of –70°C. at height 30,000 ft. is 1.1. The table on the right immediately gives the refraction *R* as 50′.

When the altitude is very small or negative, special care must be exercised in applying the *d*-correction to the altitude and in forming and naming the intercept.

Since each sight requires in general a different declination column and a different value of LHA, the reduction of two or more “simultaneous” sights to obtain a fix offers no simplification over the separate reduction of the sights.

INTRODUCTION

USE OF CORRECTING TABLES

As indicated above, corrections are required for the following, in addition to parallax (for the Moon) and refraction:

Coriolis acceleration. This correction, given in Table **7** on the inside back cover, may be applied either to each individual observation or to the fix deduced from several observations. When applied to individual observations, either the position line or the assumed position from which it is constructed must be shifted by the distance *Z* miles perpendicular to the track. The rule for applying this correction is given at the foot of Table **7**.

Motion of the observer (MOO). If it is desired to get a fix from two or more observations, the resulting position lines must be reduced to a common time, usually the time of one of them. This may be done in two ways: the position lines of observations made earlier or later than this time may be transferred on the plotting chart by the motion of the aircraft in the time-interval concerned, or the corrected sextant altitudes (or intercepts) may be adjusted to allow for the motion of the aircraft.

In the first case, the shift may be applied to the position line or to the assumed position from which it is constructed.

In the second case, the adjustment to corrected sextant altitude may be taken from Table **1** on the inside front cover, interpolating where necessary. Table **1** gives, in the upper part, the correction for a time-interval of 4 minutes, while the lower part enables this to be extended to any time-interval. By reversing the sign of this correction, it may be applied to the tabulated altitude instead of to the corrected sextant altitude, or it may be applied directly to the intercept by the rules given.

Usually, sights of several stars will be taken in rapid succession to give a fix. The example below illustrates the use of the tables for the reduction of a typical set of observations.

Example. On 1978 January 1, the following observations are obtained when flying at 385 knots on track 117°T. The observations chosen are for illustration only and are not the most suitable for a fix.

Body	GMT	Sextant altitude	Instrument error, etc.
	h m s	° ′	′
Moon	02 26 55	58 34	–6
Jupiter	02 30 55	26 25	–9
Adhara	02 35 17	45 55	–7

The DR position at GMT 02^{h} 30^{m} is S 9° 42′, E 7° 28′, height 24,000 ft., temperature –47°C.

From the *Air Almanac,*	GMT	Moon GHA	Dec.	GMT	Jupiter GHA	Dec.	GMT	*Adhara* (No.**19**) GHA	Dec.
	h m s	° ′	° ′	h m s	° ′	° ′	h m s	° ′	° ′
AM page for Jan. 1	02 20 00	321 57	N 1 14	02 30 00	48 03	N 23 12	02 30 00	137 54	
flap, increment for	6 55	1 40		0 55	0 14		5 17	1 19	
flap, SHA and Dec. of star	—	—		—	—		—	255 33	S 28 57
Sum = GHA at	02 26 55	323 37		02 30 55	48 17		02 35 17	394 46	
Assumed longitude, added because east		+7 23			+7 43			+7 14	
Sum = LHA (less 360° if necessary)		331			56			42	
		° ′			° ′			° ′	
Sextant altitude		58 34			26 25			45 55	
Sextant error, etc.		–6			–9			–7	
Refraction (Table **6**)		0			–1			0	
P. in A. (Moon)		+29			—			—	
Corrected sextant altitude (Ho)		58 57			26 15			45 48	

From these tables (pages 62, 65, 63, respectively), with assumed latitude 10°

		Dec. 1° (Contrary) Hc		d	Z		Dec. 23° (Contrary) Hc		d	Z		Dec. 28° (Same) Hc		d	Z
		°	′	′	°		°	′	′	°		°	′	′	°
Tabulated Hc, *d*, and Z for	LHA 331°	59	07	−23	109	LHA 56°	26	03	−26	122	LHA 42°	46	42	−17	60
d-correction (Table **5**) for	14′		−5			12′		−5			57′		−16		
Corrected tabulated altitude (Hc)		59	02				25	58				46	26		
Corrected tabulated altitude (Ho)		58	57				26	15				45	48		
Intercept			5	*away* Zn 071°				17	*towards* Zn 302°				38	*away* Zn 240°	

In this example, the assumed positions for all observations are taken as close as possible to the DR position at 02^h30^m; shorter intercepts can be obtained by relating the assumed positions to the DR position at the time of observation. The intercepts are plotted from the assumed positions, latitude S 10°, respective longitudes E 7° 23′, E 7° 43′, and E 7° 14′, transferred on the chart for the motion of the aircraft between the time of observation and that of the fix, and for the effect of Coriolis acceleration.

The corrections for motion of the aircraft may, however, be applied directly to the observed altitude or to the intercept. Using Table **1** corrections are obtained as follows to the observations of the Moon and *Adhara*, so that the fix will be obtained at the time of the Jupiter observation ($02^h\ 30^m\ 55^s$).

Body	Azimuth	True Track	Relative Azimuth	Table **1**	Time Interval		Correction from lower Part of Table **1** to Sext.	Alt.	Intercept	Adjusted Corr. Sext. Alt.		Adjusted Intercept	
	°	°	°	′	m	s	′	′		°	′	′	
Moon	071	117	314	+18	+4	00	+28	18	*towards*	59	15	13	*towards*
Adhara	240	117	123	−14	−4	22	+15	15	*towards*	46	03	23	*away*

The above table is largely self-explanatory; the value for the time-interval of 4^m22^s is found from the lower part of Table **1** by doubling that for 2^m11^s.

The adjusted intercepts are plotted from the same assumed positions, latitude S 10°, respective longitudes E 7° 23′, E 7° 43′, and E 7° 14′. The correction for the effect of Coriolis acceleration is applied directly to the fix. From Table **7** (inside back cover) the Z correction is found to be 2′ and the fix (or the assumed positions or position lines) must be shifted to a distance 2 miles to the left of track (southern hemisphere), i.e., in direction 027°.

Motion of the body (MOB). If the time of observation differs from that used to obtain the tabular value of LHA, the entry may still be used if a correction for the motion of the body (due to the rotation of the Earth) in the time interval is applied to the altitude (or intercept). Table **2**, on page (i), provides for this correction. It enables observations made at different times to be reduced and plotted as if they were made simultaneously, and it thus facilitates precomputation from the *Air Almanac*. Since the time used for reduction is normally the time at which the fix is desired, it is convenient to combine the corrections for motion of the body with those for the motion of the observer, as the time intervals are the same.

When both corrections are used in this way, the quantities taken from the upper parts of Tables **1** and **2** should be summed and the sum used to enter the lower parts of the tables. Alternative Tables **1** and **2**, altitude corrections for change in position respectively of the observer and body, for 1 minute of time, are included in this volume as an additional bookmark.

Example. The previous example is reduced using Tables **1** and **2**, assuming that the fix is required at GMT $02^h\ 30^m$; the sights are:

	GMT h	m	s	Sextant Altitude °	′	Corrected Sextant Altitude* °	′
Moon	02	26	55	58	34	58	57
Jupiter	02	30	55	26	25	26	15
Adhara	02	35	17	45	55	45	48

*See previous page.

The DR position at GMT $02^h\ 30^m$ is S 9° 42′, E 7° 28′, speed 385 knots on track 117°T.

From the *Air Almanac*,	GMT	Moon GHA	Moon Dec.	Jupiter GHA	Jupiter Dec.	*Adhara* (no. **19**) GHA	*Adhara* (no. **19**) Dec.
	h m	° ′	° ′	° ′	° ′	° ′	° ′
AM page for January 1	02 30	324 22	N 1 12	48 03	N 23 12	137 54	
flap, SHA and Dec. of star	—	—	—	—	—	255 33	S 28 57
Sum = GHA at	02 30	324 22		48 03		393 27	
Assumed longitude, added because east		+7 38		+7 57		+7 33	
Sum = LHA (less 360° if necessary)		332		56		41	

From these tables (pages 62, 65, 63, respectively), with assumed latitude 10°

		Dec. 1° (Contrary) Hc	*d*	Z		Dec. 23° (Contrary) Hc	*d*	Z		Dec. 28° (Same) Hc	*d*	Z
		° ′	′	°		° ′	′	°		° ′	′	°
Tabulated Hc, *d*, and Z, for	LHA 332°	60 02	−23	110	LHA 56°	26 03	−26	122	LHA 41°	47 33	−18	59
d-correction (Table 5) for	12′	−5			12′	−5			57′	−17		
Corrected tabulated altitude (Hc)		59 57				25 58				47 16		
Corrected sextant altitude (Ho)		58 57				26 15				45 48		
Intercept		1 00	*away* Zn 070°			17	*towards* Zn 302°			1 28	*away* Zn 239°	

The adjustments to these intercepts, for motion of observer and motion of body, are found as follows:

Body	Azimuth	True Track	Relative Azimuth	Table **1**	Table **2**	Sum	Time Interval	Corrections to Intercept	Adjusted Intercept
	°	°	°	′	′	′	m s	′	′
Moon	070	117	313	+17	+56	+73	+3 05	57 *towards*	3 *away*
Jupiter	302	117	185	–26	–50	–76	–0 55	18 *towards*	35 *towards*
Alpheratz	239	117	122	–13	–50	–63	–5 17	83 *towards*	5 *away*

SPECIAL TECHNIQUES

The arrangement of the tabulations in this volume, unlike that of Volume **1**, does not lend itself to any particular technique of observation and reduction. Some special techniques may, however, still be used; the principles upon which they are based are given below and users will doubtless develop methods to suit their own requirements.

1. By making the observations at predetermined times (“scheduled shooting”), the tabulated altitudes and azimuths can be extracted beforehand and the same values used both for presetting the sextant and for the subsequent reduction of the sights.

2. All corrections, normally applied to the sextant altitude, may be applied to the tabulated altitude (with reversed signs), or to the assumed position, before an observation is made, thus enabling the position line to be drawn very quickly after the observation. Care must be taken with refraction for low altitudes; the value from Table **6** may differ considerably according to whether the sextant or tabulated altitude is used as argument.

3. The Greenwich Hour Angle and declination of Sun may, if necessary, be deduced from Table **4**, on pages 246-247 for any date and time up to the year 2016 without reference to the *Air Almanac*. The error is unlikely to exceed 2′.